

Lichen biomonitoring of atmospheric quality in the National Capital Region

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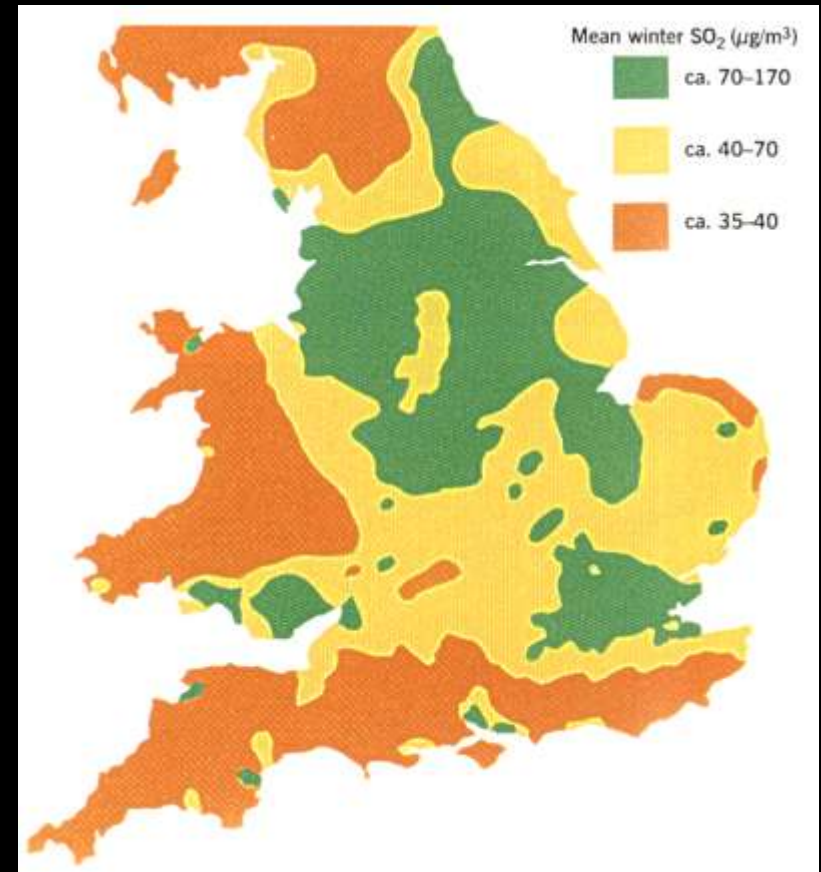
Lichens: symbiotic associations of fungi and green algae or cyanobacteria



S. Sharnoff & S. Sharnoff, North American
Lichen Project <<http://lichen.com/>>

Lichens and biomonitoring

- lichens are known to be especially sensitive or tolerant to air pollution
 - disappearance of lichens around cities
 - reappearance when air quality improves
- known sensitivities to SO_2 and metals; some sensitivities to O_3
- mapping of “indicator” lichen distributions reveals zones of varying air quality



Map of air quality based on lichen data collected by school children in England and Wales

As “air plants” lichens acquire essential elements from the atmosphere

- they will also accumulate pollutant elements when they are in the atmosphere
- changes in certain elements (S, N, metals) in the atmosphere can be monitored using lichens
- other methods frequently used in lichen studies include:
 - laboratory fumigation studies
 - K^+ efflux
 - lichen algal layer thickness



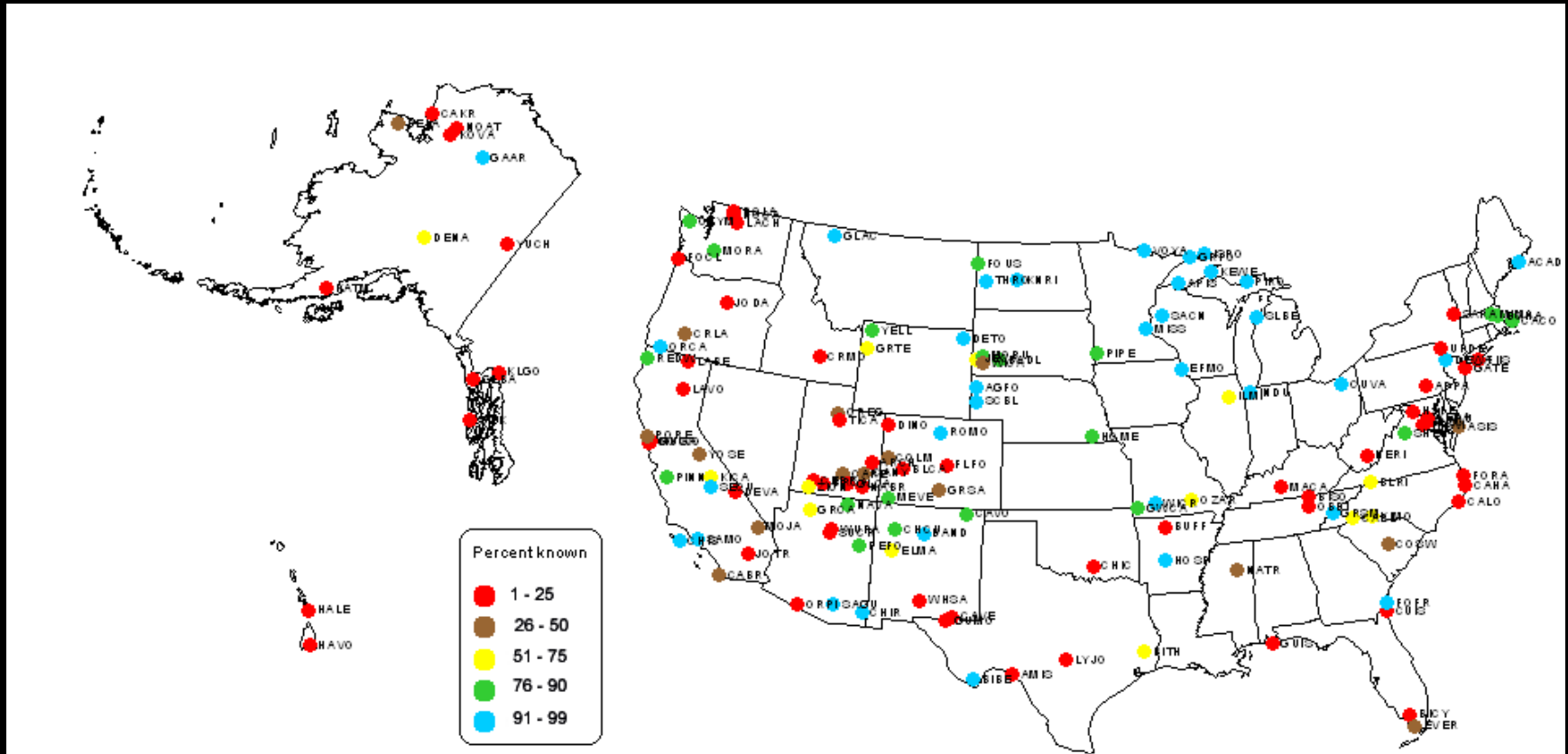
Benefits include:

- Low cost
- Integration of effects over time

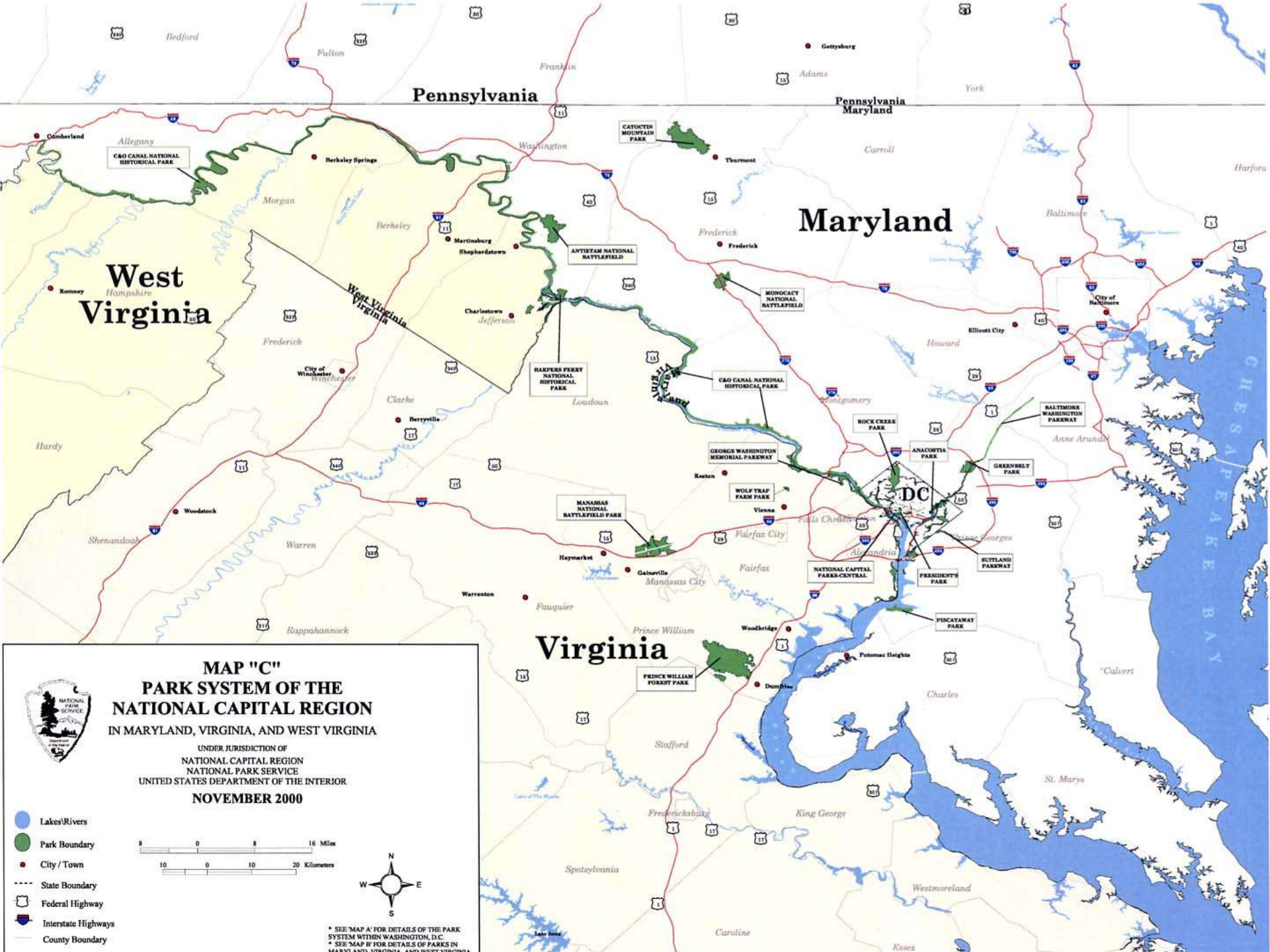
Drawbacks include:

- No clear indication of when or how much of a pollutant was in the atmosphere at any time
- Sampling sites must contain lichens suitable for sampling

USDA Forest Service and National Park Service have conducted many lichen inventory and biomonitoring studies on federal lands



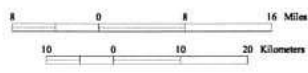
Lichen florae studied in NPS parks



MAP "C"
PARK SYSTEM OF THE
NATIONAL CAPITAL REGION
IN MARYLAND, VIRGINIA, AND WEST VIRGINIA

UNDER JURISDICTION OF
NATIONAL CAPITAL REGION
NATIONAL PARK SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR
NOVEMBER 2000

- Lakes/Rivers
- Park Boundary
- City/Town
- State Boundary
- Federal Highway
- Interstate Highways
- County Boundary



* SEE "MAP A" FOR DETAILS OF THE PARK SYSTEM WITHIN WASHINGTON, D.C.
* SEE "MAP B" FOR DETAILS OF PARKS IN MARYLAND, VIRGINIA, AND WEST VIRGINIA.

Study includes nine National Parks in NCR:

- CATO (25 sites)
- CHOH (10 sites)
- GWMP (5 sites)
- NAMA (1 site)
- NACE (5 sites)
- PRWI (44 sites)
- ROCR (3 sites)
- HAFE (5 sites)
- MANA (4 sites)

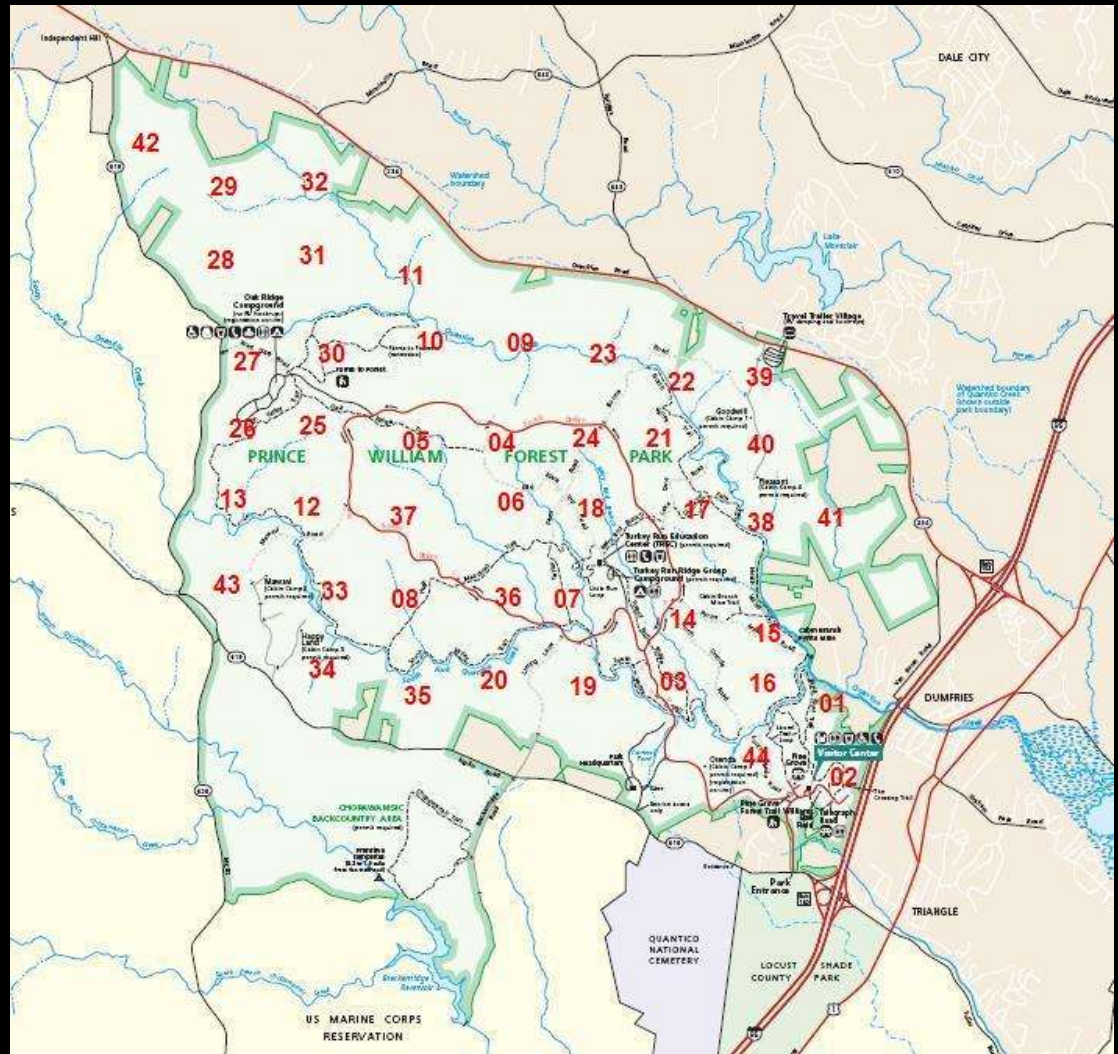


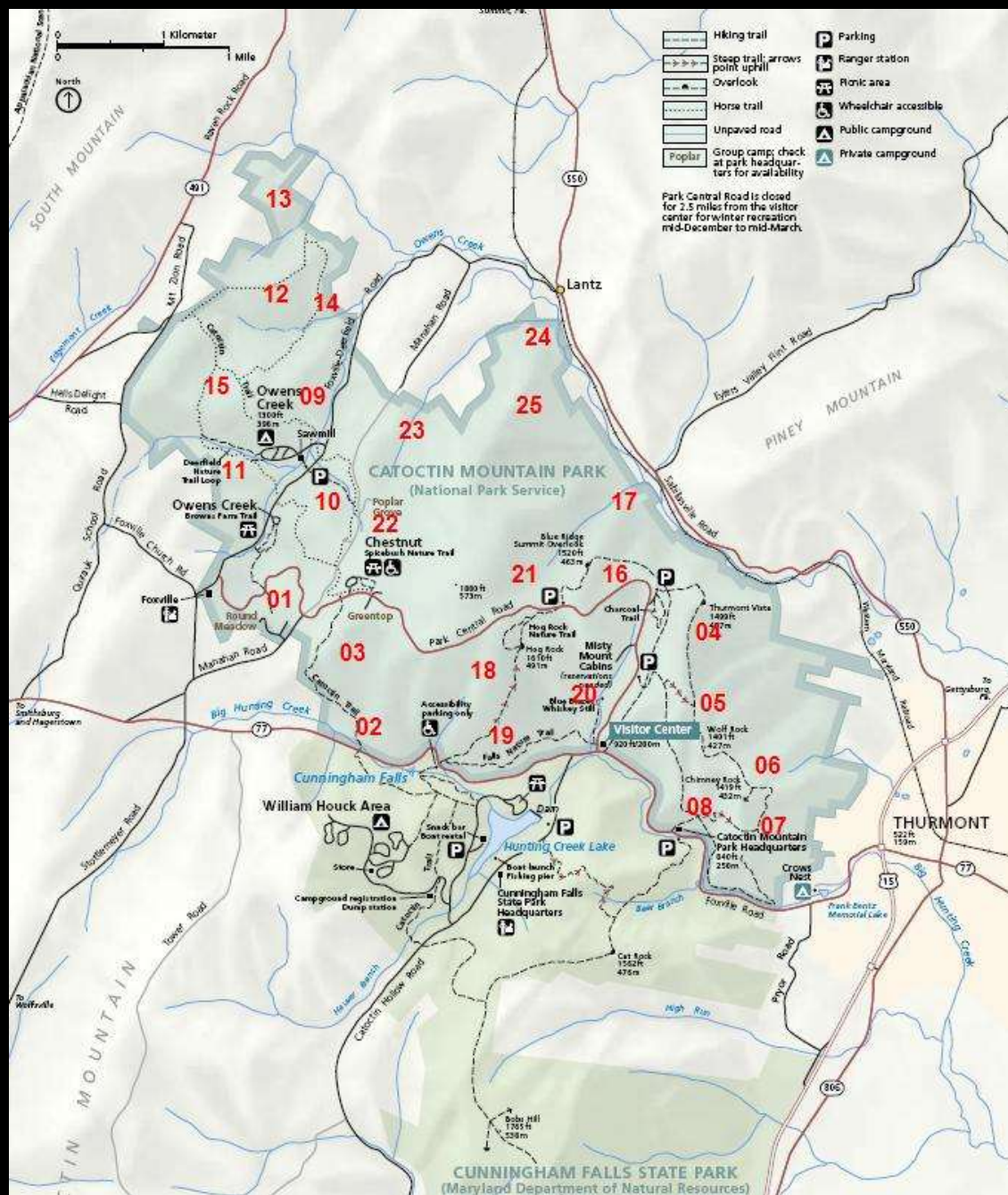
Site methods:

- 20 x 20 m quadrats (102 sites)
- GPS location
- floristic survey of macrolichens
 - presence (voucher)
 - abundance
- sample a single species (*F. caperata*) for element analysis (metals and S) at all sites
 - retrospective analysis possible in some sites (CHOH, ROCR)
 - one site (NAMA) near IMPROVE sampler at Haines Point



- In two parks (PRWI and CATO), sites are located systematically within 1 km² grids
- In the remaining parks, sites are located in representative forested areas





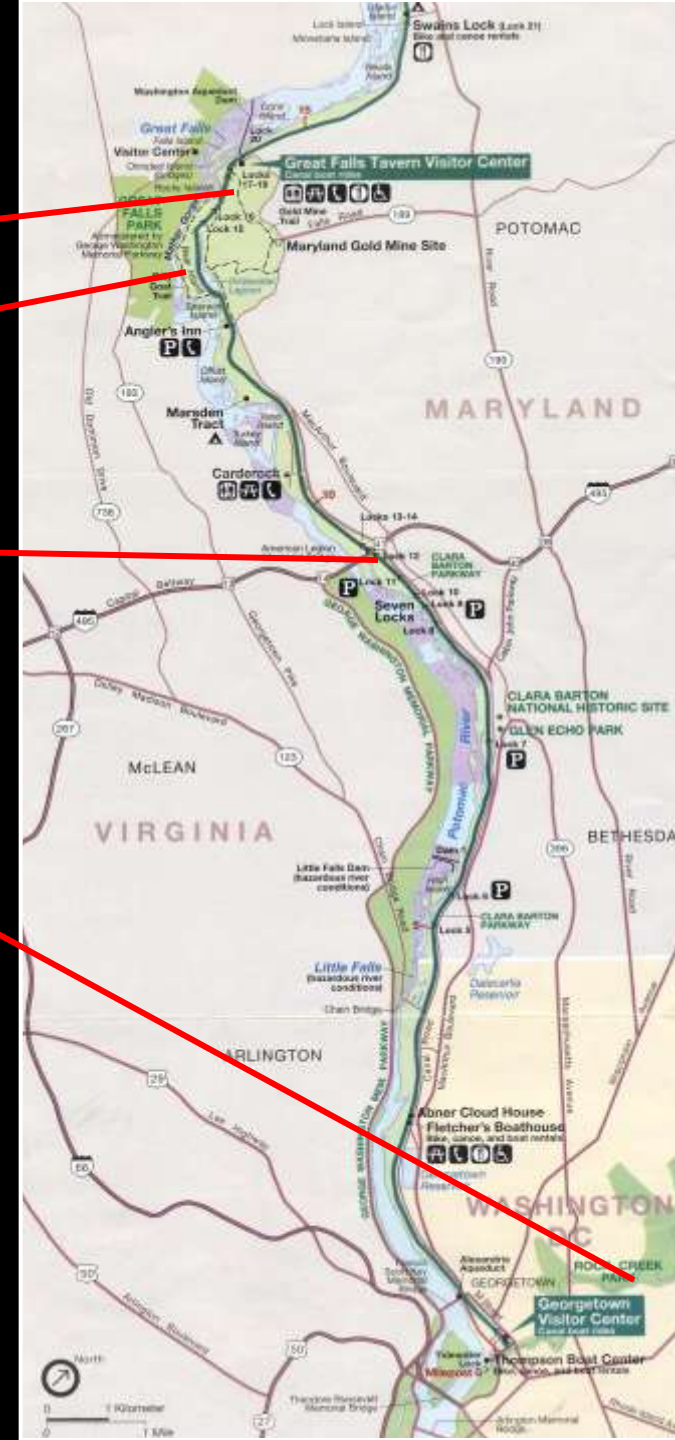
Previous studies have been done
at several sites in NCR:

Great Falls, MD

Bear Island, MD

Plummers Island, MD

Rock Creek Park, DC



WASHINGTON BIOLOGISTS' FIELD CLUB



Early surveys of nonvascular plants on Plummers Island, Maryland

- Mosses (Leonard, 1935): 82 spp.
- Fungi (Stevenson & Ermold, 1936): 221 spp.
- Hepatics (Leonard & Pierce, 1939): 18 spp.
- Lichens (Leonard & Killip, 1939): 91 spp.

Pollution-sensitive macrolichens reported from Plummers Island by Leonard & Killip (1939)

Nephroma helveticum Ach.

Collema flaccidum (Ach.) Ach.

Leptogium spp. (2)

Pannaria leucosticta Tuck.

Peltigera spp. (4)

Usnea sp. (1)

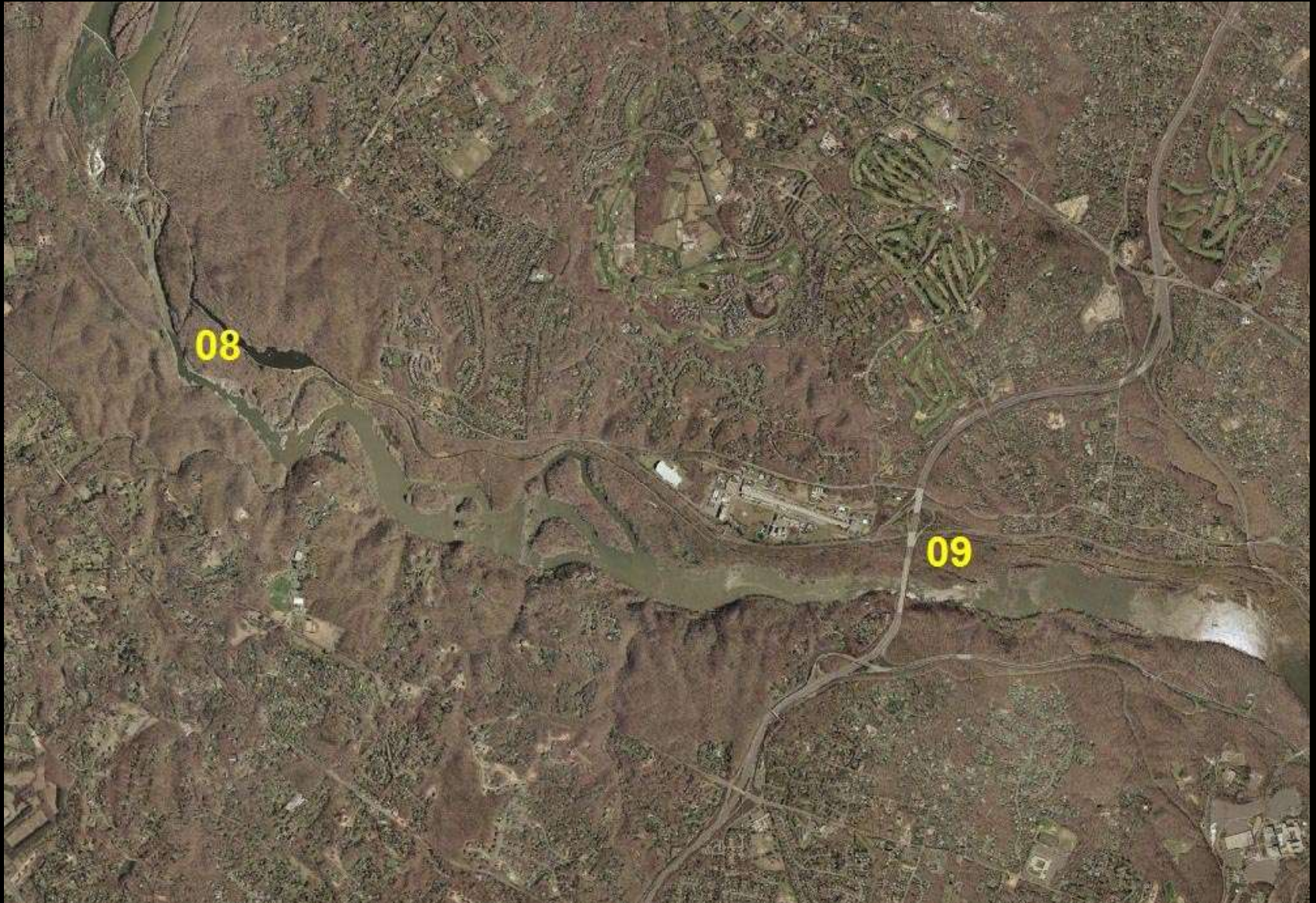


Usnea sp.



Nephroma helveticum Ach.

Plummers Island immediately below American Legion Bridge (1965); Bear Island about 6 km upstream



Previous biomonitoring studies at Plummers Island

- community studies of lichens at PI and other locations
- lichen growth response to changes in air quality
- retrospective study of Pb uptake by *Flavoparmelia baltimorensis*
- Sulfur and metals uptake by *Flavoparmelia baltimorensis* at PI and surrounding areas



Saxicolous spp Plummers Is		Stony Man	Bear Is
Flavoparmelia baltimorensis	18.61	20.81	8.64
Aspicila gibbosa	12.14		
Aspicilia cinerea	6.71	11.58	2.41
Porpidia albocaerulescens	2.44	9.86	1.17
Parmelia omphalodes	2.20	2.20	
Parmotrema crinitum	1.09		
Xanthoparmelia conspersa	1.10	0.88	0.01
Alloctraria oakesiana	1.10		
Punctelia rudecta	0.99		
Lasallia papulosa	0.98	0.08	
Xanthoparmelia cumberlandia	0.94		
Ochrolechia yasudae	0.90		
Pertusaria sp.	0.90	0.85	0.12
Lepraria zonata	0.83	1.00	0.08
Cladonia subapodocarpa	0.60	1.45	0.03
Xanthoparmelia plittii	0.24	0.62	0.01
Cetrelia chicitae		0.20	
Cladonia furcata	0.20		
Acarospora fuscata	0.14	0.02	
Usnea sp.	0.08		
Buellia disciformis	0.08	0.02	
Lecanora campestris	0.08		
Ramalina intermedia	0.08		
Imshaugia aleurites		1.74	
Rhizoplaca chrysoleuca			0.08
Physcia subtilis		0.08	
Sarcogyne sp.		0.02	0.82
Mean bare area, %	28.11	40.30	66.11
Total lichen spp.	23	15	10



Elemental Pb concentrations (mean $\mu\text{g/g} \pm \text{S.E. mean}$) in the lichen *Flavoparmelia baltimorensis*

Year	Plummers Is		Bear Is		Stony Man	
1907	82.3	8.2				
1938	127.8	14.8				
1958	327.9	12.6				
1970	1160.5	148.8				
1979	1131.0	179.3	273.0	50.6	218.5	100.9
1982	787.2	25.3	174.0	53.2		
1988	418.3	44.8	123.4	18.6	66.7	1.0
1992	136.8	7.21	49.4	3.2	25.5	2.3
2000	72.8	13.2	29.0	5.4	18.6	7.1
2004	30.7	4.7	26.4	2.7	15.5	0.7

Elemental S concentrations (mean % \pm S.E.
mean) in the lichen *Flavoparmelia baltimorensis*

Year	Plummers Is		Bear Is		Stony Man	
1983	0.250	0.005				
1988	0.186	0.015	0.207	0.006	0.134	0.011
1992	0.156	0.003	0.180	0.000	0.130	0.005
2000	0.150	0.004	0.158	0.001	0.133	0.002
2004	0.166	0.019	0.166	0.049	0.125	0.017

Preliminary (seven park units) results of element concentration from 2004 samples:

	CHOH (10 sites)		PRWI (44 sites)		CATO (25 sites)		NACE (5 sites)		MALL (1 site)		ROCR (3 sites)		GWMP (5 sites)	
S	1585.52	56.28	1320.54	14.25	1611.91	18.70	1570.33	80.72	1626.34	141.04	1503.32	58.21	1700.29	54.45
Pb	21.93	1.53	12.28	0.61	22.82	0.89	23.76	2.89	40.47	2.36	23.36	1.58	28.54	1.83
Hg	0.137	0.0004	0.129	0.0004	0.136	0.0018	0.152	0.0073	0.123	0.0130	0.133	0.0074	0.152	0.0047
Cu	18.47	1.37	11.37	0.51	14.11	0.68	14.15	1.82	24.69	13.62	20.57	4.41	22.97	3.39
Ni	2.72	0.23	Not resolvable		Not resolvable		2.27	0.41	4.53	1.20	2.19	0.14	3.10	0.41
Zn	51.99	2.61	38.97	1.54	45.42	1.28	40.21	3.84	63.88	3.98	40.91	0.65	54.28	4.54

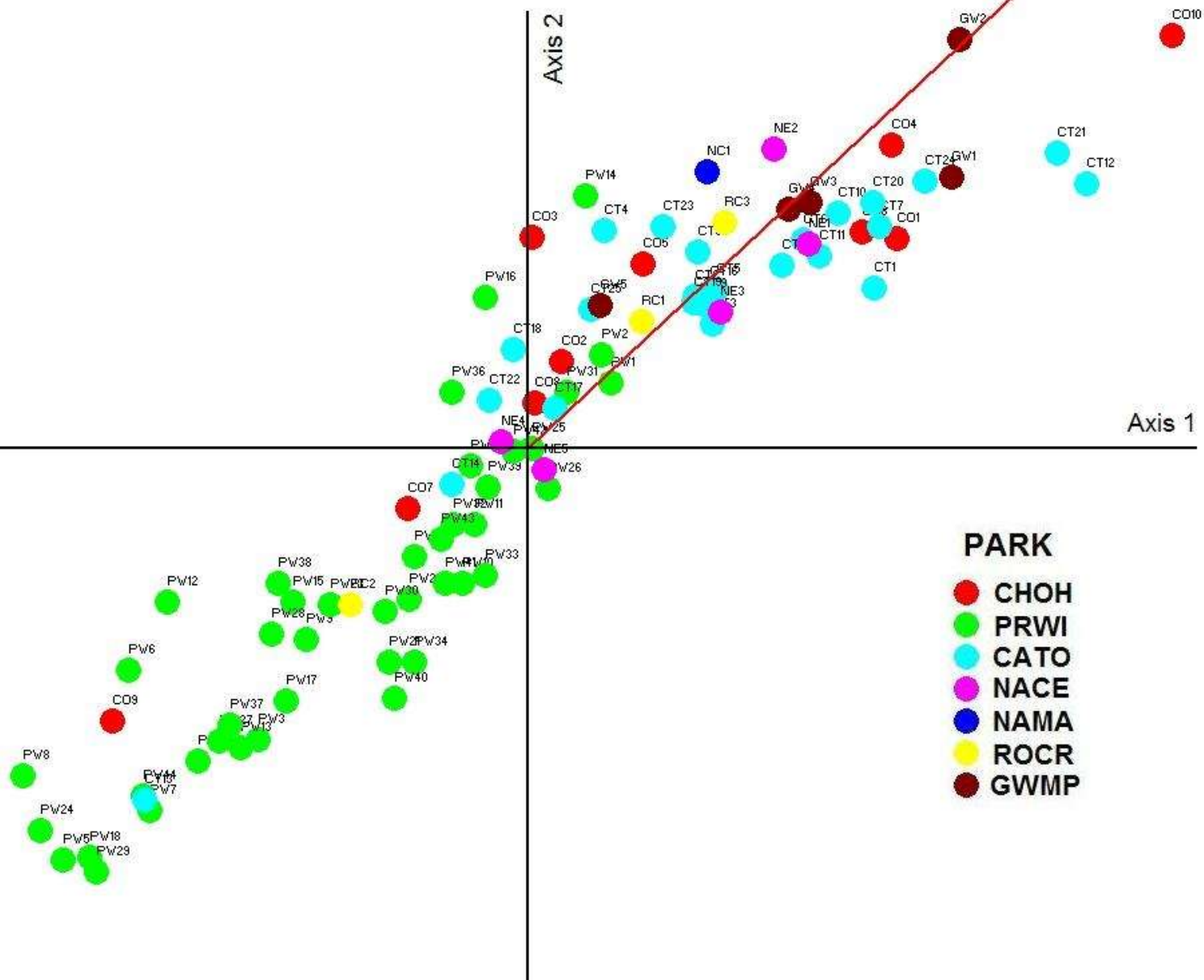
NCR sites

Axis 2

Axis 1

PARK

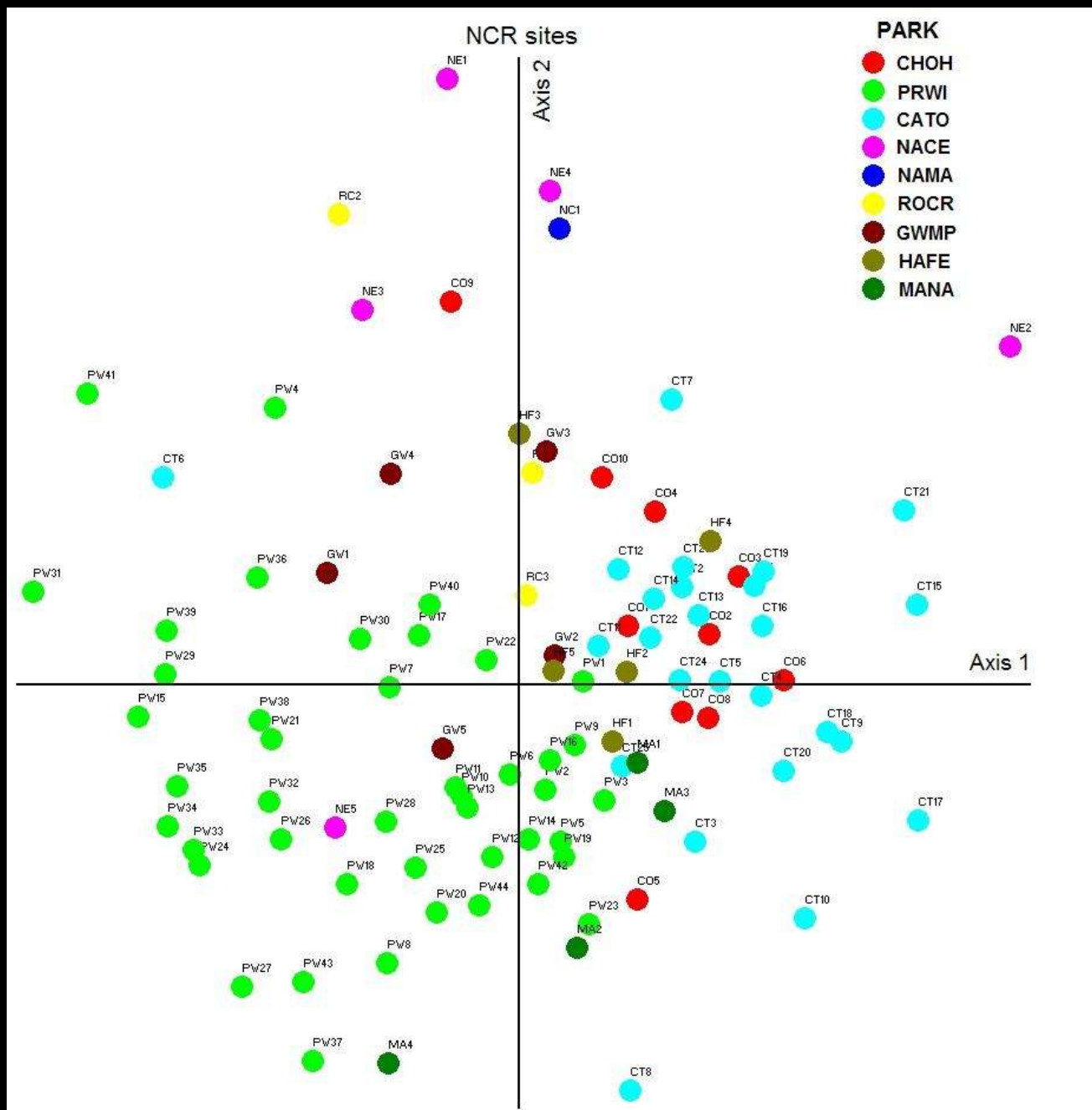
- CHOH
- PRWI
- CATO
- NACE
- NAMA
- ROCR
- GWMP



Indicator species in the NCR

Table 2. Certain species of lichens collected in the NCR study have been tentatively assigned to indicator categories based on published reports. These categories include the indicator and functional groups listed above. It should be noted that a specific lichen may be assigned to more than one grouping. (Key: S = sensitive; T = tolerant; N = nitrophilous; A = acidophilous; C = cyanolichen; para = lichenicolous fungi):

Allocetraria oakesiana S	Heterodermia speciosa	Parmotrema stuppeum	Punctelia rudecta NT
Anaptychia palmulata	Hypotrachyna livida S	Parmotrema tinctorum	Punctelia subrudecta NT
Candelaria concolor N	Leptogium cyanescens CS	Phaeophyscia adiestola	Pyxine caesiopruinosa
Canoparmelia caroliniana	Myelochroa aurulenta	Phaeophyscia orbicularis N	Pyxine soorediata
Cetrelia olivetorum S	Myelochroa galbina	Phaeophyscia pusilloides	Rimelia reticulata
Coccocarpia palmicola CS	Parmelia squarrosa S	Phaeophyscia rubropulchra N	Tuckermannopsis ciliaris AS
Collema furfuraceum CS	Parmelia sulcata NT	Phaeophyscia squarrosa	Usnea ceratina AS
Dirinaria aegialita	Parmelinopsis horrescens	Physcia aipolia N	Usnea strigosa A
Flavoparmelia caperata N	Parmelinopsis minarum	Physcia americana	Usnea sp. AS
Flavopunctelia flaventior N	Parmotrema dilatatum	Physcia millegrana NT	Athelia arachnoidea para
Flavopunctelia sooredica	Parmotrema hypotropum T	Physcia stellaris	Marchandiomyces corallinus para
Heterodermia obscurata	Parmotrema michauxianum	Physconia detersa	Nectriopsis parmeliae para



Floristic and element data suggest that nitrophilous, relatively pollution-tolerant lichen communities have developed over time in the NCR

- probably the result of poor air quality in the past and only slight improvement since
- consistent with other lichen studies done in eastern U.S.

Elemental concentrations are generally low for *Flavoparmelia caperata*

- Comparative data suggest some recent improvements in air quality
- S and Hg (and probably N) appear to be widespread pollutants

<http://mason.gmu.edu/~jlawrey/CUE/>



Introduction

Lichen bioindicators

Study objectives

Participating park units

Study methods

Site descriptions

Study results

Literature

Web resources



Lichen Biomonitoring Project

Lichens and air quality in the National Capital Region

Lichens have been recognized as indicators of air quality since the late 19th Century (Nash and Wirth 1988, Gries 1996, Henderson 2000). Many species are known to be especially sensitive or tolerant of certain air pollutants, and others are known to accumulate pollutant elements directly from the atmosphere.

Given the usefulness of lichens as bioindicators, the National Park Service (NPS) and other U.S. federal agencies have undertaken many lichen studies on federal lands during the past thirty years (Geiser and Reynolds 2002). Over 30 lichen biomonitoring programs that have been done in areas managed by the NPS.

In the National Capital Region (NCR), a number of lichen biomonitoring efforts have already been done during the past 30 years. The present study expands these efforts by establishing over 100 permanent biomonitoring sites in nine national parks in the NCR to detect and describe air pollution effects with the ultimate goal of protecting NCR resources. At each permanent study site, the abundance of all tree-inhabiting (corticolous) macrolichens has been recorded and a sample of a single common species has been taken for elemental analysis. Results are adding to information already obtained and serving as a basis for future monitoring of air quality in the NCR.



results - Windows Internet Explorer

http://mason.gmu.edu/~jlawrey/CUE/summary

Google

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results

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Lichen communities in the NCR

A total of 45 macrolichens and three lichen-associated parasites was observed in the permanent plots established during the study (Table 1). These species make up epiphytic macrolichen communities typical of the midatlantic region at the present time.

- Many of the dominant species are nitrophilous and/or pollution-tolerant (*Punctelia rudecta*, *Flavoparmelia caperata*, *Myelochroa aurulenta*, *Physcia* spp. and *Phaeophyscia* spp., *Pyxine soresdiata*), and they have likely dominated lichen communities in the eastern United States for much of the past century.
- When comparisons can be made ([see floristic data for Plummers Island, CHOH09](#)), present-day communities are less diverse and contain fewer sensitive species than communities that existed at the same sites in the past century.
- Certain lichens found only in CATO are typical northern and mountain species.
- Communities in the parks closest to the center of Washington, D.C. (NAMA, NACE) had the fewest species with the lowest abundance scores. These communities were made up mostly of pollution-tolerant, nitrophilous species (*Physcia millegrana*, *Punctelia rudecta*, *Flavoparmelia caperata*, *Phaeophyscia rubropulchra*).
- Pollution sensitive species are uncommon, but found throughout the study area (Tables 1 and 2).

Table 1. Summary of macrolichen collections made in each of the nine park units participating in the study. A link to the species lists and abundance scores is available for each entry.

	Total species	Sensitive species	Notes
CATO (25 plots)	26 macrolichens, 2 lichenicolus parasites	<i>Cetrelia olivetorum</i> , <i>Collema furfuraceum</i> , <i>Leptogium cyanescens</i>	Mountain flora (northern <i>Alloctetraria oakesiana</i> and western <i>Flavopunctelia soresdica</i>); <i>Peltigera canina</i> collected off-frame.
CHOH (10 plots)	20 macrolichens, 2 lichenicolus parasites	<i>Coccocarpia palmicola</i>	Historical floristic data available for Plummers Island, Maryland (CHOH09).
GWMP (5 plots)	15 macrolichens, 0 lichenicolus parasites	<i>Usnea</i> sp.	Historical collections from Great Falls, Maryland, available in the U.S. National Herbarium.
HAFE (5 plots)	12 macrolichens, 0 lichenicolus parasites	None	
MANA (4 plots)	20 macrolichens, 0 lichenicolus parasites	<i>Leptogium cyanescens</i> , <i>Parmelia squarrosa</i> , <i>Tuckermannopsis ciliaris</i>	
NACE (5 plots)	10 macrolichens, 0 lichenicolus parasites	None	Tolerant nitrophilous species dominant (<i>Physcia millegrana</i> , <i>Candelaria concolor</i> , <i>Punctelia rudecta</i>).
NAMA (1 plot)	6 macrolichens, 1 lichenicolus parasite	None	Tolerant nitrophilous species dominant (<i>Physcia millegrana</i> , <i>Candelaria concolor</i> , <i>Punctelia rudecta</i>).
PRWI (44 plots)	30 macrolichens, 0 lichenicolus parasites	<i>Leptogium cyanescens</i> , <i>Parmelia squarrosa</i> , <i>Tuckermannopsis ciliaris</i> , <i>Usnea ceratina</i>	<i>Collema furfuraceum</i> , <i>Peltigera canina</i> collected off-frame.
ROCR (3 plots)	10 macrolichens, 0 lichenicolus parasites	None	Historical collections available in the U.S. National Herbarium.

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Lawrey ppt files

Microsoft PowerPoint ...

PRWI - Mozilla Firefox

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PRWI Sites

Prince William Forest Park

Permanent Lichen Biomonitoring Sites in PRWI

The Prince William Forest Park is a 15,000 acre piedmont forest located 35 miles south of Washington, D.C. The park contains several rare communities, including a seepage swamp, remote stands of eastern hemlock, and several populations of rare plants. Upland slopes are dominated by mixed oak stands and lower elevations support mesic hardwood stands. Lichens are common throughout the park, especially on wind-thrown trees and branches.

PRWI sites

In 2004, 44 permanent lichen biomonitoring sites were located in 1 km² grids within the park, and a baseline sampling for lichen floristic and elemental data was done. At each location, abundance of tree-inhabiting macrolichens was recorded and a specimen of the common lichen *Flavoparmelia caperata* was collected for elemental analysis.

Links are available to the [PRWI lichen species](#) and [PRWI element data](#) collected at each sampling location. Comparative summary data for all sites in the NCR are also available.

PRWI lichens

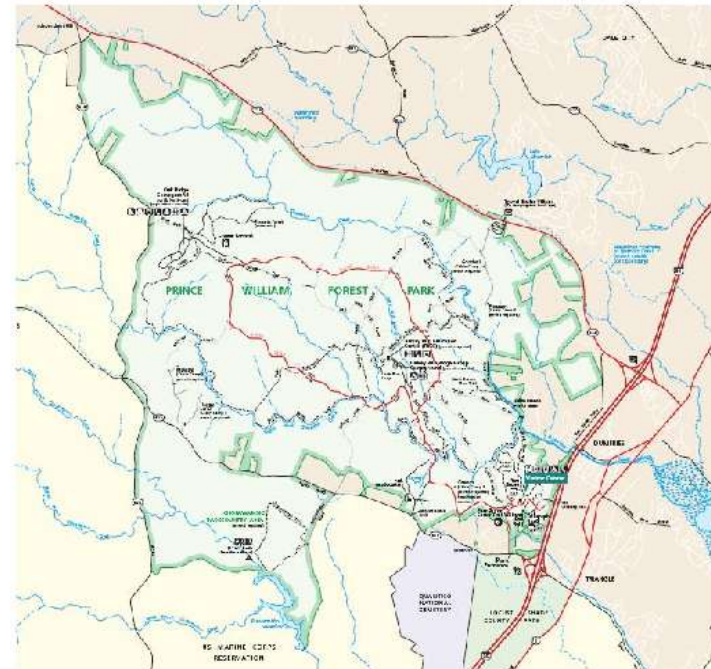
Corticolous macrolichen communities in PRWI are typical of Piedmont hardwood stands found in the Park. Dominant species include *Flavoparmelia caperata* (the species used in elemental analysis), *Punctelia rudecta*, *Pyxine sorediata*, *Parmotrema* spp., *Phaeophyscia rubropulchra*, *Physcia millegrana*, and *Myelochroa aurulenta*. *Physcia aipolia* is very common on wind-thrown branches. Species known to be sensitive to air pollution include *Usnea* spp., and the cyanolichen *Leptogium cyanescens*.

PRWI elements

Element concentrations in samples of *F. caperata* collected in PRWI are significantly lower than for all other park units studied ([descriptive summary statistics available here](#)). This is especially notable for S and Pb.

PRWI maps available from NPS

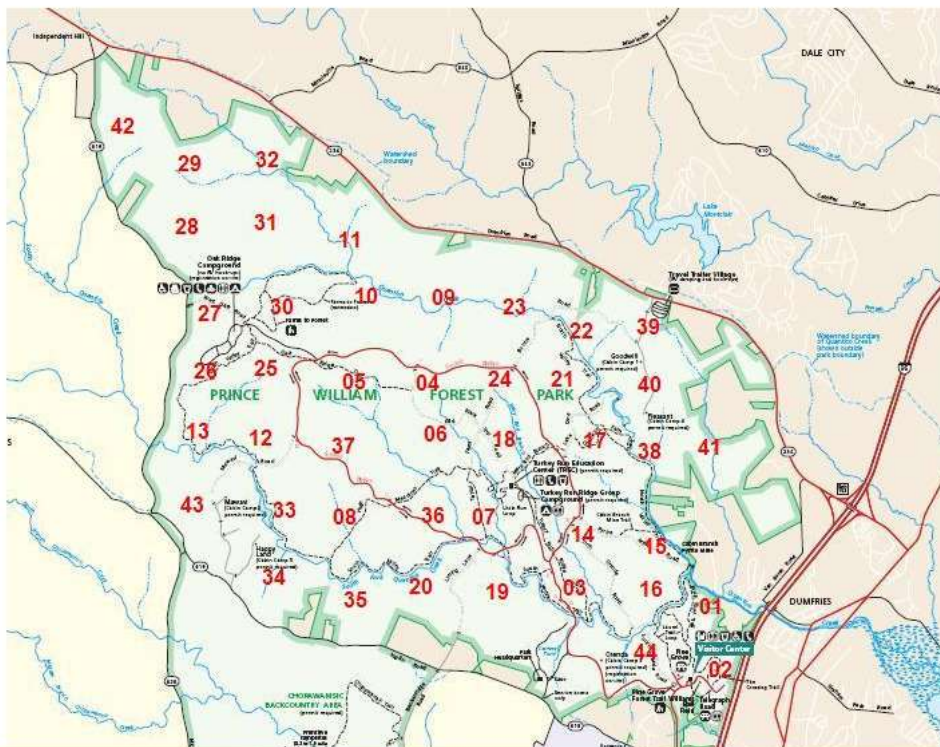
NCR Lichens Home





PRWI Sites - Site location by number

Lichen floristic data and element data (and GPS location) are available for each site





CHOH Sites

Chesapeake & Ohio Canal NHP

Permanent Lichen Biomonitoring Sites in CHOH

The Chesapeake and Ohio Canal National Historical Park was formed to encompass the 184.5-mile length of the Canal from Cumberland, Maryland to the mouth of Rock Creek in Georgetown. It includes natural floodplain forests from the foothills of the Appalachians to the tidewater Potomac near Washington, D.C.

Permanent lichen biomonitoring sites have been studied in the Park since the 1930's, and new sites have recently been added along the length of the Park. At each location, abundance of tree-inhabiting macrolichens was recorded and a specimen of the common lichen *Flavoparmelia caperata* was collected for elemental analysis.

Links are available to each site location, where all available data can be obtained. Summary data can also be obtained for all sites in CHOH.

CHOH lichens

CHOH elements

CHOH maps available from NPS

NCR Lichens Home



Links to Sites:

CHOH 01 Cumberland
CHOH 02 Oldtown
CHOH 03 Little Tonoloway
CHOH 04 Williamsport
CHOH 05 Sharpsburg
CHOH 06 Weverton
CHOH 07 Point of Rocks
CHOH 08 Bear Island
CHOH 09 Plummers Island
CHOH 10 Chain Bridge

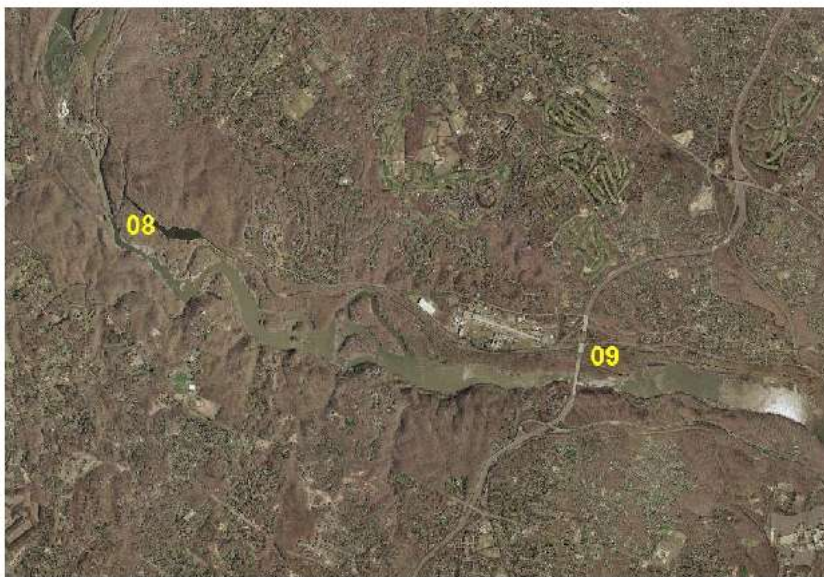


CHOH 08 Bear Island

Chesapeake & Ohio Canal NHP

Features

- Bear Island is located approximately 6 km upstream from the American Legion Memorial Bridge, and has been included in lichen biomonitoring studies since the 1970's.
- The Billy Goat Trail, one of the most popular with hikers, runs across much of Bear Island.
- Bear Island lies within the Potomac River Gorge, one of the most significant hyrogeologic features in the Park, and site of many rare and unusual plant species.
- **Studies of lead accumulation** by the rock-inhabiting lichen *Flavoparmelia baltimorensis* indicate that fallout patterns have changed significantly in the past 100 years.



Site data

38.9821N 77.2366W
Oak-hickory forest

Corticololous lichens in plot 2004 (abundance)

Anaptychia palmulata (1)
Coccocarpia palmicola (1)
Dirinaria aegialita (1)
Flavoparmelia caperata (4)
Heterodermia obscurata (2)
Myelochroa aurulenta (4)
Parmotrema dilatatum (2)
Phaeophyscia adiastrata (1)
Phaeophyscia rubropulchra (3)
Physcia millegrana (4)
Punctelia rudecta (4)
Punctelia subrudecta (2)
Pyxine caesiopruinosa (2)
Marchandiomyces corallinus (1)

2004 Element data (mean $\mu\text{g/g} \pm$ SD, N = 3)

Cd < 0.54
 Cu 22.16 ± 3.31
 Cr 1.93 ± 0.45
 Pb 26.40 ± 2.70
 Ni 2.41 ± 0.52
 Zn 35.85 ± 8.22
 S 1474.7 ± 126.8
 Hg 0.13 ± 0.02

National Park Service

National Park Service
U.S. Department of the Interior



Center for Urban Ecology

Natural Resources and Science
National Capital Region

District of Columbia, Maryland
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